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THE DISTANCE TRAVELLED FROM REST TO TERMINAL VELOCITY BY A SPHERE IN AIR (U)

by



Stanley B.\Mellsen

Project No. 20-90-03 WUD 13E01



September 1978 /



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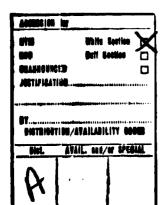
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THE DISTANCE TRAVELLED FROM REST TO TERMINAL VELOCITY BY A SPHERE IN AIR (U)

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ABSTRACT

The distance travelled as a function of velocity for falling spherical drops starting from rest was calculated. This was done for 1 to 5 millimetre spheres to determine the travel distance required for designing experiments where velocities approaching terminal are required. The results showed that 80 percent of terminal velocity is reached after spheres of unit density and diameter of 5 millimetres have fallen from rest through a distance of 7.5 metres. To achieve 85 percent of terminal velocity, an increase of only 5 percent, 9.5 metres is required. Also calculated was the velocity of particles blown upward from rest in a vertical airstream. This was done to provide information for comparison of experimental to theoretical results on the effect of dust on aerodynamic drag.

(U)

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NOTATION

a and b	simplifying constants
c _D	drag coefficient of a sphere in air
D	drag force due to air resistance
d	spherical drop diameter
g	acceleration due to gravity
m	mass of sphere
^m e	effective mass of sphere in air due to buoyancy effects
Re	Reynolds number of a sphere
t	time after sphere starts to move
u	free stream air velocity
V	velocity of sphere
٧*	upward terminal velocity of a sphere in a vertical air stream
۷ _s	slip velocity of a sphere in a vertical air stream
v _t	terminal velocity of a spherical particle
x	displacement of sphere from rest
Υ	surface tension of the liquid
μ	dynamic viscosity of air
ν	kinematic viscosity of air
ρa	air density
P	density of the liquid

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THE DISTANCE TRAVELLED FROM REST TO
TERMINAL VELOCITY BY A SPHERE IN AIR (U)

by

Stanley B. Mellsen

INTRODUCTION

The immediate purpose of this report is to provide information on the velocity as a function of distance fallen from rest for drops of various sizes of interest, and to describe the method by which this was achieved. The second purpose is to describe the determination of the upward velocity of spherical dust particles in a vertical stream of air. This information was necessary for comparing experimental to theoretical results in a study of impaction forces of dust on spheres and cylinders (Mellsen).

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The mathematical theory and the solution of the equations of motion, for which computer programs are provided, are described herein.

2. THE PROBLEM

It has been shown experimentally that drops of various liquids falling through air deform to a negligible extent provided that the value of $\rho_{\ell}d^2g/\gamma$ is below 0.4. For ordinary liquids this limiting value corresponds to drops which are l=1.5 mm in diameter, and the terminal velocities reached, under any atmospheric conditions, by drops smaller than this can be calculated precisely from knowledge of the fluid resistance offered to the motion of spheres (Batchelor).

The work reported herein was undertaken to determine the distance travelled to terminal velocity by droplets 1 - 5 mm in diameter under any atmospheric conditions. Although this range of drop sizes falls outside the limiting value described above, the assumption of spherical drops was used. This provides sufficient accuracy for the purpose of designing experimental apparatus. The exact discrepancies were not obtained but they are certainly less than the discrepancies in the terminal velocities themselves, which were obtained by comparing the calculated terminal velocities of spheres to those of water drops determined by Best's empirical equation (Batchelor). The reason that the discrepancy in distance travelled to terminal velocity is less than the discrepancy in the terminal velocity is that the drag force gradually increases as the drop travels from rest to terminal velocity, and, correspondingly, the distortion of the drop increases to maximum deviation from spherical shape at terminal velocity.

3. THE MATHEMATICAL SOLUTION

a) Terminal Velocity of Spherical Drops

Equating the drag acting on a rigid sphere of diameter d and density ρ_{ℓ} , falling with steady velocity v_t to the effective weight of the sphere in air of density ρ_a , we have:

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$$\frac{C_D \pi d^2 \rho_a v_t^2}{8} = \frac{\pi (\rho_{\ell} - \rho_a) d^3 g}{6}$$
 (Eq. 1)

where C_D , the drag coefficient, is a function of the Reynolds number Re = vd/v which characterizes the motion of the sphere (Batchelor). Hence:

$$v_t^3 = \frac{4(\rho_{\ell} - \rho_a)gvRe^2}{3\rho_a C_D Re}$$
 (Eq. 2)

Eq. 2 was solved by an iterative technique. This was necessary because the drag coefficient is dependent upon the Reynolds number in a complex way so that the equation could not be solved explicitly for $\mathbf{v_t}$. The dependency of drag coefficient on Reynolds number has been determined by a set of definitive equations for $\mathbf{C_DRe}$ (Davies) based on the results of many experiments. These were solved for each Reynolds number as required by means of Newton's method. The initial estimate of $\mathbf{C_DRe}$ chosen for use in Eq. 2 was the Stokes flow value of 24. This was substituted into Eq. 2 which was then solved for $\mathbf{v_t}$. This value of $\mathbf{v_t}$ was then used to calculate $\mathbf{C_DRe}$ which was in turn substituted into Eq. 2 and the process repeated. This iterative procedure was tested and found to converge rapidly.

The calculations for the terminal velocity were done by means of a subroutine in the computer program (Subroutine SBM 36, Appendix A). The values of $C_D^{\rm Re}$ needed in these calculations were obtained from a function subprogram (Function CDRE (RE), Appendix A).

b) Distance Travelled from Rest in Still Air as a Function of Velocity

The equation of motion of a spherical particle falling in air is given by:

$$m_{e}g - D = \frac{mdv}{dt}$$
 (Eq. 3)

$$m_{e} = \frac{\pi d^{3}(\rho_{\ell} - \rho_{a})}{6}$$
 (Eq. 4)

$$m = \frac{\pi d^3 \rho_{\ell}}{6}$$
 (Eq. 5)

and

$$D = \frac{C_D \pi d^2 \rho_a v^2}{8}$$
 (Eq. 6)

To obtain the quantity $C_{\overline{D}}Re$ for use in later calculations, the following form for the drag coefficient was used:

$$C_{D} = \frac{\mu C_{D}Re}{vd\rho_{a}}$$
 (Eq. 7)

Then, using Eq. 7, substitution of Eqs. 4, 5 and 6 into Eq. 3 gives the following equation for time from rest as a function of velocity:

$$t = \int_{0}^{v} \frac{dv}{a - bvC_{D}Re}$$
 (Eq. 8)

where

$$a = 9 \left(1 - \frac{\rho_a}{\rho_{\ell}} \right)$$
 (Eq. 9)

and

$$b = \frac{3\mu}{4\rho_g d^2}$$
 (Eq. 10)

Recognition that dx = vdt gives the following equation for displacement as a function of velocity:

$$x = \int_{0}^{V} \frac{v dv}{a - bvC_{l}Re}$$
 (Eq. 11)

Eqs. 8 and 11 were solved by means of a computer program (Appendix A). The terminal velocity was first calculated by a subroutine (SBM 36, Appendix A) and the velocity increased by one percent increments up to ninety eight percent of terminal velocity, because terminal velocity is asymptotic. The quantity $C_{\mathsf{D}}\mathsf{Re}$ was found in each step by the function sub-

program (CDRE (RE), Appendix A) and substituted in Eqs. 8 and 11 with the value of v to solve for t and x at each succeeding velocity.

c) Distance Travelled Upward From Rest in a Vertical Air Stream

The solution to this problem is similar to that of the problem described in the previous subsection with the following exceptions. The upward terminal velocity of the spherical particle is:

$$v_* = u - v_+$$
 (Eq. 12)

where \mathbf{v}_{t} is terminal velocity calculated in air at rest as discussed earlier. The slip velocity of the particle, defined as the relative velocity between the air stream and sphere, is:

$$v_{e} = u - v$$
 (Eq. 13)

Eq. 6 becomes:

$$D = \frac{C_D \pi d^2 \rho_a v_s^2}{8}$$
 (Eq. 14)

Then Eqs. 8 and 11 become:

$$t = \int_{0}^{V} \frac{-dv}{a - bv_s C_D Re}$$
 (Eq. 15)

$$x = \int_{0}^{V} \frac{-v dv}{a - bv_s C_D Re}$$
 (Eq. 16)

The latter two equations were solved by a computer program (Appendix B) which was similar to the one previously described (Appendix A). The velocity was incremented by one percent of the upward terminal velocity instead of one percent of the terminal velocity in still air. The final increment was then at ninety percent of the upward terminal velocity, the asymptotic velocity in this particular case.

4. RESULTS

The elapsed times, velocities, distances, and fractions of terminal velocities were calculated for spheres of unit density falling from rest in still air. These are shown for diameters of 1 to 5 millimitres in 1/2 millimetre increments in the tables immediately following the listing of the computer program by means of which they were calculated (Appendix A). Also shown are the terminal velocities and, for comparison, the terminal velocities of water drops from Best's equation (Batchelor). The results are illustrated in the form of velocity versus distance curves for 1, 2, 3, 4 and 5 millimetre spheres (Fig. 1), and in terminal velocity versus diameter curves for rigid spheres compared to water drops (Fig. 2).

The elapsed times, velocities, distances travelled, and fractions of upward terminal velocities were calculated for spheres of specific gravity 2.6, corresponding to the density of glass beads used in experiments (Mellsen) on spheres starting from rest in a vertical air stream. An example of the results of these calculations is shown in the table following the listing of the computer program by means of which they were obtained (Appendix B). The results are illustrated in the form of curves of upward sphere velocity versus upward air velocity for three particle diameters (Fig. 3). These diameters and the distance travelled were used in previous experiments to measure drag on spheres and cylinders in dusty air. The results shown (Fig. 3) were used for comparison of theory to the results of these experiments and reported elsewhere (Mellsen). The program listed (Appendix B) was also used to provide direct numerical values for that work.

5. DISCUSSION

As can be seen (Fig. 1) better than 80 percent of terminal velocity was reached by the time spheres of unit density and maximum diameter of 5 millimetres had fallen from rest through a distance of 7.5 metres.

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To achieve 85 percent of terminal velocity, an increase of only 5 percent, a distance of 9.5 metres was required. This indicated that, if a drop tube is to be used in experiments, a great deal of increase in length is required to gain little increase in velocity when approaching terminal velocity. However, a useful consequence of this asymptotic behavior is that the percentage of terminal velocity acquired by liquid drops is closely approximated by calculated percentages for spherical particles. The difference between terminal velocity for spheres of unit specific gravity and water drops increases with drop size (Fig. 2). However, the difference in percentage of terminal velocity reached for drop sizes of 1 to 5 millimetres is still negligible from the point of view of impaction test accuracy.

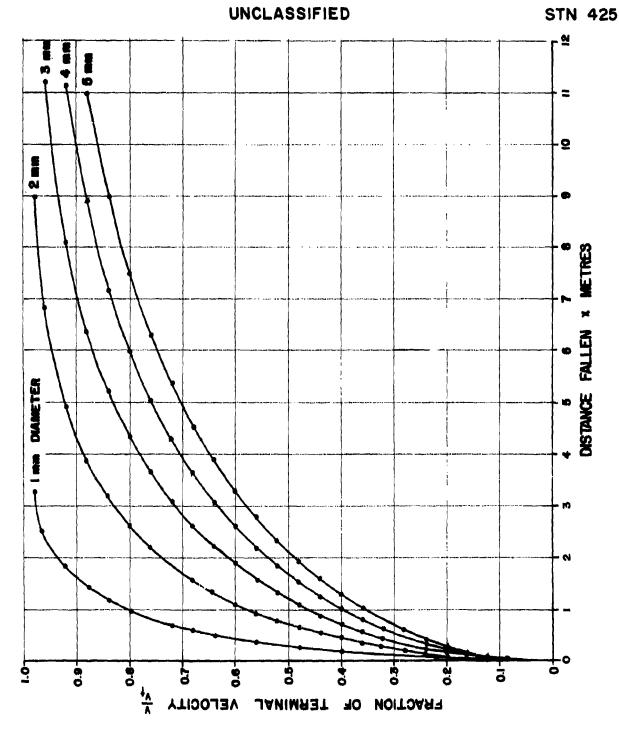
The curves of sphere velocity versus upward air velocity for a travel distance of 95 centimetres (Fig. 3) showed that terminal velocities were not reached for air velocities above 480 and 550 centimetres per second for particle diameters of 0.0470 and 0.0155 centimetres, respectively. Consequently, terminal velocities were not reached in experiments to which other calculations were compared (Mellsen). The applications and consequences of these results are described in the same reference.

6. CONCLUSIONS

Results of velocity versus distance for drops falling in still air and spherical dust particles blown upward in an air stream were obtained. These results are useful in the design or analysis of experiments where optimum travel distances are required or where travel distances are confined to available working space.

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Davies, C.N.	1945	"Definitive Equations for the Fluid Resistance of Spheres". The Proc. of the Physical Society. Vol. 57, Part 4. July 1945.
Mellsen, S.B.	1978	"The Impaction Force of Airborne Particles on Spheres and Cylinders". Suffield Technical Paper No. 486. UNCLASSIFIED.



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Figure 1: Velocity vs Distance for Spheres of Unit Density Falling from Rest in Still Air at 15°C

and 76 cm Hg Pressure

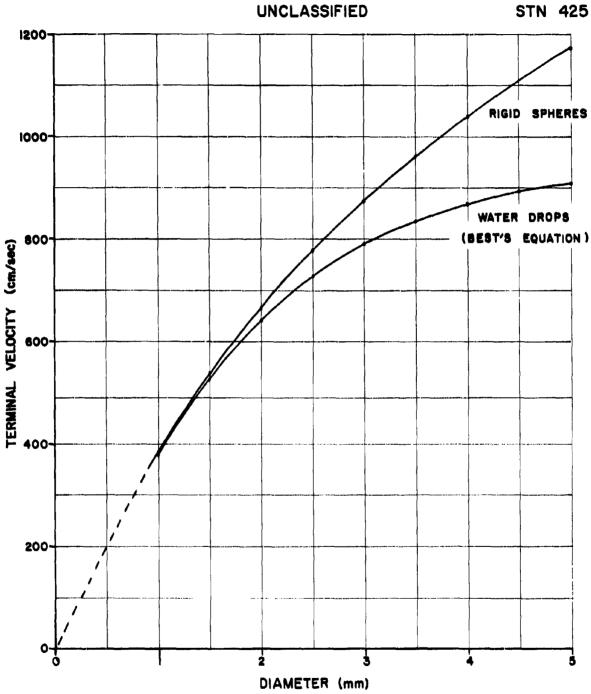


Figure 2: Terminal Velocities of Spheres of Unit Density Falling in Air at 15°C and 76 cm Hg Pressure

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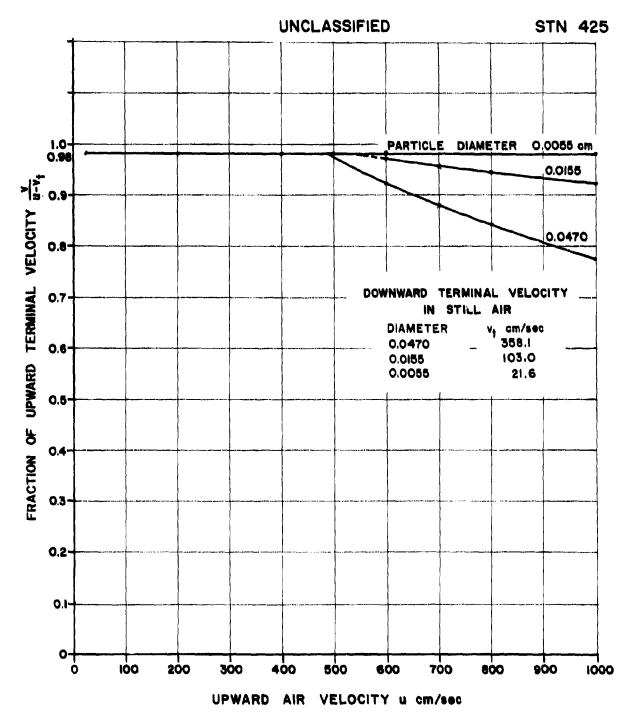


Figure 3: Upward Velocity of Spheres of Density 2.6 g cm⁻³ Starting From Rest 95 cm Upstream in a Vertical Air Stream at 15°C and 76 cm Hg Pressure

APPENDIX A

COMPUTER PROGRAM FOR DISTANCE TRAVELLED
FROM REST TO TERMINAL VELOCITY FOR
SPHERES IN STILL AIR

// JOB T // JOB T

							1=0006 A4(R)=0008 B0(R)=000A 1=0012 FX(R)=0014 FPX(R)=0016 1=001E ITER(I)=0028
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= #F10.7/10H RHO = #F10.6/ F10.6/10H XMU = #F10.7/10H RE = #E10.4} TERMINAL VELOCITY IS #F10.3 & CM/SEC OH THE DISTANCE DROPPED IN AIR AS A FUNCTION OF H VELOCITY GROW REST /1H0 SH TIME.17x. 9H VELOCITY.13x.9H DISTANCE.8X. ATIO 1x,4H SEC #19x.7H CM/SEC #16x.3H CM #17x.5H V/VT 5. 13X.F10.3 #11X.F10.3 #13x.F6.3 E TERMINAL VELOCITY OF A LIGUID DROP BY BEST'S EQUAT BHO(RC)=7FFC SIGMA(RC)=7FFA XMU(RC)=7FFB RE(RC)=7FF6 AIR = #0002 BER #=0004 DELXIR #=0006 X KR #=0008 VRIR =0012 VIBIR #=0012 VIBIR #=0014 ISSI =001A NSTOPL =0018	100 FORMALIANTO					
FIO.6/10H XWU = #F10.7/10H RE = #E10.4) TERMINAL VELOCITY IS #F10.3 & A CM/SEC OH THE DISTANCE DROPPED IN AIR AS A FUNCTION OF H VELOCITY BY A SPHERICAL PARTICLE OF GIVEN DIAMETER SOH STRATING FROM REST /1H0) SOH STRATING FROM REST /1H0 SOH STRATING FROM REST /1H0 IX.4H SEC #19X.7H CM/SEC #16X.3H CM #17X.5H V/VT 5. 13X.F10.3 *11X.F10.3 *13X.F6.3 *1 S. 13X.F10.3 *11X.F10.3 *13X.F6.3 *1 ATIO IX.4H SEC #19X.7H CM/SEC #16X.3H CM #17X.5H V/VT S. 13X.F10.3 *11X.F10.3 *13X.F6.3 *1 ATIO IX.4H SEC #19X.7H CM/SEC #16V.3H CM #17X.5H V/VT BH CM/SEC #1 AIR #2000 BELTIR #2000 DELXIR #20012 VIBIR #20014 IS. IT #2001 VIBIR #20014	SOU FORMATTIONS	AF10-7/10W				
TERMINAL VELOCITY IS *F10.39 8H CM/SEC) OH THE DISTANCE DROPPED IN AIR AS A FUNCTION OF H VELOCITY BY A SPHERICAL PARTICLE OF GIVEN DIAMETER 20H STARTING FROM REST /1H0) 20H STARTING FROM REST /1H0) 30H STARTING FROM REST /1H0 1X,4H SEC *19X.7H CM/SEC *16X.3H CM *17X.5H V/VT 5. 13X.F10.3*11X*F10.3*13X*F6.3) E TERMINAL VELOCITY OF A LIQUID DROP BY BEST'S EQUAT 8HO(RC)=7FFC SIGMA(RC)=7FFA XMU(RC)=7FF8 RE(RC)=7FF6 AIR 1=0002 BER 1=0004 DELV(R 1=0012 VTB(R 1=0014 1S.(1 1=001A NSTOP(I)=0018 1S.(1 1=001A NSTOP(I)=0018	110H SIGMA =	•	-10.7/10H RE	•E10.4}		
DH THE DISTANCE DROPPED IN AIR AS A FUNCTION OF H VELOCITY BY A SPHERICAL PARTICLE OF GIVEN DIAMETER 20H STARTING FROM REST /1H0] 20H STARTING FROM REST /1H0] 5H TIME:17x, 9H VELOCITY:13x,9H DISTANCE:8x, ATIO 1x,4H SEC :19x,7H CM/SEC :16x,3H CM :17x,5H V/VT 5. 13x,F10.3:11x,F10.3:13x,F6.3) E TERMINAL VELOCITY OF A LIQUID DROP BY BEST'S EQUAT 8H CM/SEC : AKR 1=0002 BER 1=0004 DELVIR !=0012 VIBIR !=0014 1St !=0014 NSTOP! !=0018	201 FORMAT (27HOTHE	TERMINAL VELOCITY	IS .F10.3, 8H CM/S	EC 1		
H VELOCITY BY A SPHERICAL PARTICLE OF GIVEN DIAMETER 20H STARTING FROM REST /1H0) 5H IME:17x, 9H VELOCITY:13x,9H DISTANCE:8X. AIIN 1X,4H SEC	FORMAT (1HO.	OH THE DISTANCE	DRCPPED IN AIR AS A	FUNCTION OF		
20H STARTING FROM REST /1H0) 5H TIME:17x 9H VELOCITY:13x;9H DISTANCE:8X; ATIO 1x,4H SEC 19x,7H CM/SEC 16x;3H CM 17x,5H V/VT 5 13x,F10.3;11x,F10.3;13x,F6.3; E TERMINAL VELOCITY OF A LIQUID DROP BY BEST'S EQUAT 8H CM/SEC 1 RHO(RC)=7FFC SIGMA(RC)=7FFA XMU(RC)=7FFB RE(RC)=7FF6 A(R 1=0002 B(R 1=0004 DELVIR 1=0012 VIB(R 1=0014 IS) IS IT 1=0018 VRIR 1=001A NSTOP(I 1)=0018		H VELOCITY BY A SPI	HERICAL PARTICLE OF	GIVEN DIAMETER		
5H IIWE:17x: 9H VELOCITY:13x.9H DISTANCE:8X. ATIO 1x.4H SEC :19x.7H CM/SEC :16x.3H CM :17x.5H V/VT 5* 13x.F10.3:11x.F10.3:13x.F6.3! E TERMINAL VELOCITY OF A LIQUID DROP BY BEST'S EQUAT BH CM/SEC ! A LIQUID DROP BY BEST'S EQUAT RHO(RC)=7FFC SIGMA(RC)=7FFA XMU(RC)=7FFB RE(RC)=7FF6 ARR 1=0002 BR 1=0004 DELXIR 1=0006 XRR 1=0008 VR R 1=0002 DELTIR 1=0010 DELXIR 1=0012 VIBIR 1=0014 IST 1=001A NSTOPL 1=0018	<u>.</u>	20H STARTING FROM !	REST /1H0)			
ATIO 1X,44 SEC	203 FORMATITHO.	114E,17X,	H VELOCITY 13X 9H DI	STANCE, 8X,		
1x,4H SEC	115H VELOCITY R	1	i	!		
E TERMINAL VELOCITY OF A LIQUID DROP BY BEST'S EQUAT BH CM/SEC) RHO(RC)=7FFC SIGMA(RC)=7FFA XMU(RC)=7FFB RE(RC)=7FF6 A(R)=0002 BER)=0004 DELY(R)=0012 VIB(R)=0014 VR(R)=0001 NSTOP(I)=0018	/2		7H CM/SEC +16X+3H CM	11X,5H V/VT		
5- 13% F10-3-11% F10-3-13% F6-3) E TERMINAL VELOCITY OF A LIQUID DROP BY BEST'S EQUAT BH CM/SEC 1 BH CM/SEC				!		
E TERMINAL VELOCITY OF A LIQUID DROP BY BEST'S EQUAT 8H CM/SEC 1 RHG(RC)=7FFC SIGMA(RC)=7FFA XMU(RC)=7FFB RE(RC)=7FF6 A(R 1=0002 B(R 1=0004 DELV(R 1=0002 VIB(R 1=0014 IS(1 1=0018 IS(1 1=0014 IS(1 1=0018 IS(1	FURWATI	5. 13X #F10.3 #11X #F.	10.3.13X.F6.3)			
8H CM/SEC) RHO(RC)=7FFC SIGMA(RC)=7FFA XMU(RC)=7FFB RE(RC)=7FF6 A(R)=0002 B(R)=0004 DELY(R)=0016 VR(R)=0016 DELI(R)=0012 VIB(R)=0014 IS(I)=001A NS(OP(I)=001B	FORMAT (E TERMINAL VELOCIT	Y OF A LIGUID DROP B	Y BEST'S EQUAT		
RHO(RC)=7FFC SIGMA(RC)=7FFA XMU(RC)=7FFB RE(RC)=7FF6 A(R)=0002 B(R)=0004 DELY(R)=0006 X(R)=0008 VR(R)=000E DELI(R)=0010 DELX(R)=0012 VTB(R)=0014 15(1)=001A NS(OP(1)=001B		8H CM/SEC 1				
RHO(RC)=7FFC SIGMA(RC)=7FFA XMU(RC)=7FFB RE(RC)=7FF6 A(R)=0002 B(R)=0004 DELY(R)=0006 X(R)=0008 VR(R)=000E DELI(R)=0010 DELX(R)=0012 VIB(R)=0014 IS(I)=001A NS(OP(I)=001B	OM-3					
A(R)=0002 B(R)=0004 DELY(R)=0006 X(R)=0008 VR(R)=000E DELT(R)=0010 DELX(R)=0012 VTB(R)=0014 IS(T)=0018	VARIABLE ALLOCALIONS DP(RC)=7FFE		SIGMA (RC)=7FFA	XMU(RC1=7FF8	RE (RC) = 7FF6	VT(RC)=7FF4
VRIR = 000E DELICE	0000-1000	A / D 1=0002	4000=1 a/a	ACC 418 1=0006	X (D 1=0008	AUD 1=000A
)#0010 1 1 1 1 1 1 1	7000=1 A1TE	2000=1 a/aV		DELY (R. 1=0006	#100=1 #1X	TERCI SECOND
		15(T 1=001A		***************************************	170-1 410-1	

STATEMENT ALLOCATIONS 100 =0031 111 =003 22 =0208 23 =020	IONS =0034 200 =020E 24	*3035 20 =021A 20	201 ±005E 26 =021A	202	=0232	63 = 008	IC 204	=00F2 26	203 =00BC 204 =00F2 205 =00FA	T	=0138 21	=3202
FEATURES SUPPORTED ONE WORD INTEGERS 10CS					•			·				
CALLED SURPROGRAMS												
SAM36 CORE FE	FEXP FAXB	FADS SIOF	FMPY S101	FDIV	7.0	FSTO	FSBR	FDVR	FAXI	FLOAT	CARDZ	PRNTZ
• EAL CONSTANTS • 981000E 03=001C • 177000E 00=0029	.100000E 01=001	01=001E	.75000	.750000E 00=0020	020	•10000CE	.10000GE 03=0C22		*000000E 00=0024		*943000E 03*0026	03=0026
INTEGER CONSTANTS 2=002C 3=	3€ GZ90=è	98=002E	1=002F	:	4×0030							
CORE REQUIREMENTS FOR COMMON 12 VARIABLES	OR I ABLES	28 PROGRAM	24M 536	٠								
END OF COMPILATION												
//_xE0				:	;		:					

0.1000000	3.001213	1.000000	0.00017B9	0.2634F 03
	W			
ď	SH P	SIGMA	∩•×	u Or

THE TERMINAL VELOCITY IS 388.914 CM/SEC

THE DISTANCE DROPPED IN AIR AS A FUNCTION OF VELOCITY RY A SPHERICAL PARTICLE OF GIVEN DIAMETER STARTING FROM PEST

0-030	600*0	0.039	0.079	0.119	0.159	0.199	0.239	0.279	0.319	0.359	0*366	0.439	0.479	0.519	0.559	0.599	0.639	0.679	0.719	0.759	0.799	0.839	0.879	0.919	0.959	626*0
000-0	0.015	0,155	C+564	1.236	2,183	3.422	4.970	6.851	760*6	11.732	14,806	18,369	22.481	27.224	32.696	39.029	46.395	55.030	65.265	77.592	92.779	112,127	138,121	176.503	246.843	325.566
0.00-0	0 00 00 00 00 00 00 00 00 00 00 00 00 0	15.556	31,113	46.669	62.226	77.782	93.339	108.896	124.452	140.009	155.565	171,122	186.679	202,235	217.792	233,349	248.905	264.461	280.018	295.575	311,131	326.688	342.244	357.801	373,358	381,136
0.0000	76600-0	0.01596	0.03213	0.04857	0.06537	0.08257	0.10025	0.11850	0.13740	0.15705	0.1775P	0.19912	0.22186	0.24599	0.27180	0.29962	0.32991	G+3632R	0.40059	0.44311	0.49282	0.553CF	0.63027	0.73916	69666	1.1374#
	000*0	0.000 3.889 0.015	0.000 0.000 3.889 0.015 15.556 0.155	0.000 0.000 3.889 0.015 15.556 0.155 31.113 0.564	0.000 3.889 15.556 31.113 46.669 1.236	0.000 0.000 3.889 0.015 15.556 0.155 31.113 0.564 46.669 1.236 62.226 2.183	0.000 0.000 3.889 0.015 15.556 0.155 31.113 0.564 46.669 1.236 62.226 2.6183	0.000 0.000 3.889 0.000 0.000 15.556 0.155	0.000 3.889 15.896 0.015 15.556 0.155 46.669 62.226 62.226 77.782 93.339 108.896 6.851	0.000 0.000 3.889 0.005 15.556 0.015 31.113 0.554 46.669 1.236 62.226 2.183 77.782 3.422 93.339 4.970 124.452 9.094	0.000 0.000 3.889 0.005 15.556 0.015 31.113 0.015 46.669 0.155 62.226 0.356 62.226 2.183 77.782 3.422 93.339 4.970 108.896 6.970 124.652 9.094 140.009 11.732	0.000 3.889 15.556 0.015 11.13 0.564 46.669 0.155 1.236 6.8226 2.183 77.782 93.339 108.896 14.806 155.565 14.806	0.000 3.889 15.556 31.113 6.264 46.669 1.26469 1.26469 1.26452 9.339 1.08.896 1.26452 1.26	0.000 3.889 15.556 0.015 31.113 6.564 6.669 1.236 6.226 77.782 9.339 108.896 118.972 154.452 9.094 11.732 155.565 140.009 11.732 155.565 140.609 11.732 155.565 140.609	0.000 0.000 1.5889 0.015 1.5856 0.015 31.113 0.0015 31.113 0.0264 46.669 0.226 0.226 0.226 0.226 0.226 0.226 0.226 0.226 0.226 0.226 0.226 0.226 0.226 0.226 0.226 0.226	0.000 3.889 15.556 0.015 15.556 31.113 62.226 62.226 62.226 77.782 93.339 108.896 108.896 14.806 171.122 155.565 11.732 18.369 171.122 18.369 171.122 18.369 17.822 17.	0.000 3.889 15.556 0.015 31.113 6.264 6.2669 1.2669 1.2669 1.26.83 1.26.83 1.26.896 1.26.896 1.6.896 1.6.896 1.6.896 1.6.896 1.6.896 1.6.896 1.6.896 1.6.896 1.6.896 1.732 1.71.122 1.8.369 1.8.36	0.000 3.889 15.556 31.113 0.015 31.113 0.0564 4.6.669 1.2.26 0.3.25 0.3.26 0.3.26 0.3.26 0.3.22 0.3.3.42 0.3.43 0.3.43	0.000 3.889 1.889 0.005 15.856 0.015 11.13 0.005 0.015 11.13 0.005 0.015 10.256 0.2564 0.2564 0.2564 0.2565 0.2564 0.2565 0.2564 0.2565 0.2564 0.2565	0.000 3.889 15.856 15.856 0.015 15.856 62.226 62.226 77.782 93.339 108.896 108.896 14.806 14.806 111.732 155.565 18.697 202.235 24.836 202.235 24.8490 26.851 26.85	0.000 3.889 15.556 15.556 31.113 6.6226 62.226 62.226 77.782 93.339 108.896 108.896 14.806 171.122 155.565 111.732 18.369 202.33 34.9 202.35 2	0.000 3.889 15.556 15.556 31.113 6.2564 46.669 1.236 6.2226 777.782 93.339 108.896 108.896 108.896 1718.22	0.000 3.889 15.556 15.556 31a.113 0.015 31a.113 0.0564 46.669 0.155 93.339 03.339 03.339 03.339 03.339 03.349 03.3	0.000 1.889 1.889 1.889 1.8856 1.8155 1.8113 1.826 6.854 1.826 1.826 1.826 1.826 1.826 1.826 1.826 1.826 1.826 1.826 1.826 1.836 1.826 1.826 1.826 1.831 1.831 1.831 1.831 1.831 1.831 1.831 1.831 1.831 1.831 1.831	0.000 3.889 15.856 15.856 31.113 6.669 6.2.26 6.2.26 6.2.26 77.782 93.339 108.896 108.896 14.806 140.009 110.732 155.865 140.009 110.732 125.865 140.009 110.732 20.2.33 20.698 20.295 20.295 20.203 2	0.000 3.889 15.856 15.856 31.113 6.6264 46.669 6.226 6.226 6.226 77.782 93.39 108.896 108.896 14.806 14.806 14.806 14.806 18.861 202.23 202.2481 202.23 248.905 248.905 256.461 266.461 280.018 266.461 280.018 266.461 280.018 266.461 280.018 266.461 280.018 266.461 280.018 266.461 280.018 266.461 280.018 266.461 280.018 266.461 280.018 266.461 280.018 266.461 280.018 266.461 280.018 266.65 295.255 311.131 373.358 373.358 373.358

382.079 CM/SEC THE TERMINAL VELOCITY OF A LIGUID DROP BY BEST'S EQUATION IS

0.1500000	0.001213	1.00000	0.00017R9	0.5511E 03
н	H			
a C	CH &	SIGWA	N X	u. Or

,这是就是这个人的,是是不是的人,我们就说到了我就看出我的人的说话,我们也是这些人的,我们也是一个一个,这个人的人的人,也是一个人的人,也是一个人的人的人,也是 1995年,我们就是这个人的,我们就说到了我就看出我的人的人的人的人的人,我们也是一个人的人的人,也是一个人的人的人,也是一个人的人的人,也是一个人的人的人,也是

THE TERWINAL VFLOCITY IS 541.892 CM/SEC

THE DISTANCE DROPPED IN AIR AS A FUNCTION OF VELOCITY BY A SPHERICAL PARTICLE OF GIVEN DIAMETER STARTING FROM REST

VELOCITY RATIO V/VT	000*0	0.010	0.040	0.000	0.119	0.160	0.199	0.239	0.280	0.320	0-359	0.399	0.439	0.479	0.519	0,560	0.600	0,640	0.679	0,719	0.759	0.799	0.840	0.879	0.920	0.959	0.980
DIS'ANCE CM	000*0	0.030	0.301	1.092	2.390	4.214	6.594	9,562	13,161	17.441	22.465	28.306	35.060	42.840	51.792	62,101	74.005	87.822	103.986	123+110	146,096	174,359	210,298	258,489	329,514	459.429	604.647
VELOCI TY CM/SEC	3.000	5.418	21,675	43.351	65.027	86.702	108.378	130.054	151,730	173,405	195.081	216.757	238.432	260,108	281,784	303.460	325,135	346.811	368.487	390.162	411.838	433,514	455,190	476.865	498.541		531.055
114E SEC	0.0000	0.00553	0.02221	0.04467	0.06746	0.09067	0.11440	0.13873	0.16379	0.18967	0.21653	0.24452	0.27384	0.30470	0.33740	0.37229	0.40983	0.45061	0.49544	0.54547	0.60239	0.65877	0.74910	0.85180	0.99643	1.24951	1.52409

530.666 CM/SEC THE TERMINAL VELOCITY OF A LIGUID DROP BY BEST'S EQUATION IS

90	4	0.2000000
O T		0.001213
SIGMA	H	1.000000
Ω M X	M	0.0001789
RE		0.9088E 03

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THE TERWINAL VELOCITY IS 670.230 CM/SEC

THE DISTANCE DROPPED IN AIR AS A FUNCTION OF VELOCITY BY A SPHERICAL PARTICLE OF GIVEN DIAMETER STARTING FROM REST

:																						:					
VELOCITY RATIO	00000	0000	0.039	0,079	0.119	0.159	0.199	0,239	0.279	0.319	0.359	0*399	0.439	0.479	0.519	0,559	669*0	0.639	0.679	0.719	0.759	0,799	0.839	0.879	0,919	0.959	0.979
DISTANCE	000.0	0.045	0.460	1.668	3.646	6.423	10,039	14.543	19,995	26.468	34.053	42.860	53.026	64.720	78.153	93.599	111.408	132.050	156.161	184.646	218.834	260.813	314,117	385.494	490.546	682,435	896.697
VELOCITY CM/SEC	00000	6.702	26.809	53.618	80.427	107,236	134.046	160.855	187.664	214.473	241,283	268-092	294.901	321.710	348.520	375,329	402.138	428.947	455.756	482.566	509.375	536.184	562,993	589.803	616,612	643,421	656.826
TI SEE	0000000	0.00684	0.02745	0.05517	0.08326	0.11183	0.14098	0.17083	0.20152	0.23317	0.26597	0.300.9	0.33576	0.37227	0.41294	0.45521	0.50062	0.54987	766030	0.66419	0.73263	0-81236	0.90868	1,03157	1,20463	1.50686	1.83441

644.536 CM/SEC THE TERMINAL VELOCITY OF A LIGUID DROP BY BEST'S EQUATION IS

00	13	8	68	96
0.250000	0.0012	1.0000	0.0001789	0.1323E
	14	H	H	W
90	Ç E	SIGWA	⊃w ×	a H

THE TERMINAL VELOCITY IS 780.660 CM/SEC

THE DISTANCE DROPPED IN AIR AS A FUNCTION OF VELOCITY BY A SPHERICAL PARTICLE OF GIVEN DIAMETER STARTING FROM REST

·					
VELOCITY RATIO	0.000 0.009 0.039 0.039 0.139	0.199 0.239 0.279 0.319 0.399	0.439 0.479 0.519 0.559 0.599	0.679 0.720 0.759 0.879 0.879	0.919 0.959 0.980
DISTANCE	0,000 0,062 0,624 7,936 8,690	13.571 19.644 26.986 35.693 45.883 57.700	71,324 86,977 104,937 125,562 149,317 176,816	208.902 246.763 292.156 347.828 418.443 512.897	651.765 905.151 1187.883
VELOC1TY CM/SEC	0.000 7.806 31.224 62.448 93.672 124.896	156.120 187.344 218.568 249.792 281.016	343.464 374.668 405.912 437.912 458.360 458.860	530.808 562.032 593.256 624.480 655.928	718-152 749-376 764-988
TIME	0.00C00 0.00797 0.03196 0.06420 0.05683	0.16377 0.19834 0.29882 0.27037 0.38420	0.3R856 0.43167 0.47721 0.42568 0.37667	0.69580 0.76456 0.84257 0.93336 1.08267	1.37897 1.72164 2.09275

729.616 CM/SEC THE TERMINAL VELOCITY OF A LIGUID DROP BY BEST'S EQUATION IS

				877.296 CM/SEC
C.3000000 C.501213	1.00000	0.0001789	C.1784E 04	7Y 1S
	* 4	M		TERM
9 8 0 10 0 10	SIGHA	⊋×	e œ	Ŧ

THE DISTANCE DROPPED IN AIR AS A FUNCTION OF VFLOCITY BY A SPHERICAL PARTICLE OF GIVEN DIAMETER STARTING FROM REST

								1 2																			
VELOCITY RATIO	0,000	0.010	0.040	0.080	0.120	0,160	0.199	0.240	0.280	0.320	0.359	6600	0.439	0940	0.519	0*260	009*0	0*9*0	0.679		0.759	0.799	0.840	0.879	0.920	0.960	0.979
DISTANCE	00000	0.078	0.786	2.852	6.226	10.954	17-097	24.731	33,953	44.878	57.651	72.450	89.494	109.056	131,482	157,209	186.811	221.047	260.956	308.003	364.356	433.408	520.913	637.854	809.625	1122.762	1471.950
VELOCITY CM/SEC	00000	8.772	35.091	70.183	105.275	140,367	175.459	210.551	245.642	280.734	315.826	350.918	386.010	421-102	456.194	491,285	526.377	561.469	596.561	631.653	666.745	701-837	736.928	772.020	807.112	842.204	859.750
TIME	0.0000	0.0089£	0.03591	0.07210	0.10871	0.14586	0.18370	0.22236	0.26201	0.30283	0.34502	0.34682	0.43452	0.48245	0.53305	0.58684	0.64450	0.70691	0.77529	0.85131	0.93749	1-03769	1.15849	1.31244	1.52849	1.90529	2.31211

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791.973 CM/SEC

THE TERMINAL VELOCITY OF A LIGUID DROP BY BEST'S EQUATION IS

0.3500000	0.001213	1.000000	0.0001769	0.2285E 04
- dG	e CHG	SIGMA =	* DEX	# #
•				

THE TERMINAL VELOCITY IS 963.235 CM/SEC

THE DISTANCE DROPPED IN AIR AS A FUNCTION OF VELOCITY BY A SPHERICAL PARTICLE OF GIVEN DIAMETER STARTING FROM REST

00000	600 • 0	0.039	0.079	0.119	0.159	0.199	0.239	0.279	0.319	0.360	0,399	0.439	0.479	0.519	0.559	0.595	0.639	0.680	0.720	0.759	0.799	0.840	0.879	0,919	0.959	0.980
0.000	0.094	646.0	3.436	7.497	13.184	20.567	29.736	40.801	53.900	69.203	86.918	107,303	130,681	157-458	188-152	223.441	264.220	311,718	367.667	434.630	516.618	620.434	759.066	962.545	1333,199	1746,329
0.000	9.632	36.529	77.058	115,588	154-117	192.647	231,176	~	. 6 71	346.764	385.294	423.823	462,353	500.882	539.411	577.941	616.470	655.000	693.529	732.059	770.588	809-116	847.647	886,176	924.706	943.971
0.0000	0.00983	0.03941	0.07912	0. 925	0, 0, 0	0. 138	0.24367	0.28700	0.33158	0.37761	0.42536	0.47514	0.52732	0.5R235	0.64080	0.70340	0.77110	0.84522	0.92757	1,02083	1,12919	1.25973	1.42595	1.65904	2.06526	2.50471
	000000 00000 (0.000 0.000 9.632 0.094	0.000 0.000 3 9.632 0.094 1 38.529 0.949	0.000 0.000 9.632 0.094 38.529 0.949 77.058 3.436	0.000 0.000 9.632 0.094 1 38.529 0.949 77.058 3.436	0.000 0.000 9 9632 0.094 1 36,529 0.949 77,058 3.436 115,588 7.436	100 0.000 0.000 183 9.632 0.094 1841 38,529 0.949 112 77.058 3.436 115,588 7.497 196 154.117 13.184 192.647 20,567	0.000 0.000 9.632 0.094 1 36.529 0.949 77.058 3.436 115.588 7.497 1 192.647 20.517	100 0.000 0.000 83 9.632 0.694 141 38.529 0.949 122 17.058 3.436 123 115.588 1.497 194 154.117 13.184 194 192.647 20.567 100 269.705 40.801	100 0.000 0.000 9.632 0.004 9.632 0.094 112 77.058 3.436 125 115.568 7.497 126 154.117 13.184 138 192.647 20.567 167 231.176 29.736 100 269.705 40.801 58 308.235 53.900	100 0.000 0.000 483 0.000 0.000 484 38.529 0.949 112 77.058 3.436 125 115.588 7.497 126 154.117 13.184 192.647 20.567 167 231.176 29.736 100 269.705 40.801 58 368.235 53.900 61 346.764 69.203	100 0.000 0.000 9.632 0.094 141 38.529 0.949 112 77.058 3.436 125 115.588 7.497 126 15.517 13.184 127 13.184 192.647 20.567 167 231.17 20.567 20.567 100 269.705 40.801 58.205 136 346.205 53.800 346.203 346 136 66.203 36.203	100 0.000 0.000 9.632 0.094 141 38.529 0.049 122 115.588 1.497 123 154.117 13.184 167 2647 20.567 167 29.736 40.801 58 30.8235 53.90 61 346.764 66.918 164 423.823 107.303	100 0.000 0.000 9.632 0.004 112 38.529 0.949 112 77.058 3.436 125 115.588 7.497 196 154.117 13.184 197 23.176 29.736 100 269.705 40.801 58 346.764 69.203 61 365.294 66.2918 136 453.823 107.303 114 452.353 130.681	100 0.000 0.000 9.632 0.004 4.1 38.529 0.949 1.12 77.058 3.436 1.15.588 1.6497 1.96.117 1.3.184 1.92.647 20.567 1.00 2.69.715 1.00 2.69.705 40.801 1.98 368.235 53.900 1.14 423.823 1.07.303 1.14 423.823 1.07.303 1.35 500.882 1.57.458	100 0.000 0.000 9632 0.004 9632 0.094 112 77.058 3.436 125 115.588 7.497 126 154.117 13.184 196 192.647 20.567 100 259.176 29.756 100 269.235 53.900 61 368.235 53.900 61 385.294 86.918 114 462.353 107.803 40 59.411 188.152 180 599.411 188.152	100 0.000 0.000 9.632 0.094 141 38.529 0.049 112 77.058 3.436 125 115.588 7.497 126 15.647 20.567 167 231.17 20.567 167 29.736 40.801 168 36.256 53.900 169 36.256 60.801 160 36.256 60.801 114 462.355 107.303 126 425.824 86.918 130 4681 107.303 130 539.411 1851.52 140 577.941 223.441	100 0.000 0.000 9.632 0.004 112 77.058 3.436 125 115.588 7.497 126 154.117 13.184 196 156.117 20.567 100 20.705 40.801 58 308.235 53.900 61 36.254 66.918 114 423.823 107.303 114 423.823 107.303 115 500.882 130.681 114 423.823 137.458 114 423.823 137.458 115 59.411 223.441 110 577.941 264.220	100 0.000 0.000 9.632 0.004 112 77.058 3.436 125 115.568 7.497 126 154.117 13.184 127 12.184 13.436 128 13.437 13.184 100 269.705 40.801 58 368.235 40.801 114 423.823 107.303 126 500.882 130.681 135 500.882 137.458 136 539.411 2264.220 140 577.471 2264.220 120 615.500 311.718	100 0.000 0.000 9.632 0.004 461 38.529 0.949 112 17.058 3.436 125 115.588 17.497 196 154.117 13.184 197 13.184 13.284 198 195.176 29.736 100 269.705 40.801 58 308.235 40.801 114 423.294 86.203 115 462.353 107.303 116 422.353 130.681 10 590.411 188.152 10 516.470 26.220 10 517.494 223.441 10 616.677 26.220 10 616.677 26.220 10 517.841 26.220 10 616.677 26.220 10 616.677 26.220 10 517.841 26.220 10 616.677 26.200 20	100 0.000 0.000 183 9632 0.004 184 38.529 0.949 112 77.058 3.436 125 115.588 7.497 126 127.057 13.184 192.647 20.7567 20.7567 100 269.705 40.801 126 269.705 53.900 14 423.355 107.801 14 423.359 130.681 15 462.353 130.681 160 539.411 188.152 160 539.411 223.441 160 616.470 21.7458 160 655.000 31.718 17 655.000 31.718 183 223.441 223.441 183 225.441 223.441 183 225.441 225.441 183 225.441 225.441 183 225.441 225.441 183 225.441 225.441 </td <td>100 0.000 0.000 9.632 0.094 112 77.058 3.436 125 115.588 7.497 126 154.117 13.184 167 2647 20.567 167 231.17 20.567 167 249.705 40.801 58 308.235 53.900 61 346.764 69.203 114 423.823 107.303 126 423.823 130.681 137 462.353 130.681 138 53.441 223.441 10 616.470 264.220 550.00 311.718 57 656.20 454.630 57 656.20 454.630 10 616.470 264.230 10 616.41 223.441 10 616.420 454.630 10 616.400 454.630 10 616.641 454.630 10 616.641</td> <td>100 0.000 0.000 183 9.632 0.004 112 77.058 3.436 125 115.588 17.497 126 115.588 17.497 127 115.588 17.497 128 195.117 13.184 196 195.117 29.736 100 269.705 40.801 58 38.235 53.900 61 386.764 86.918 114 423.823 107.303 115 59.41 123.441 120 516.823 130.681 130 616.470 253.441 140 616.470 253.441 150 616.470 311.718 150 616.470 311.718 150 616.470 311.718 150 616.470 311.718 150 616.470 311.718 160 616.418 51.646 170.588 516.618 516.618 <</td> <td>100 0.000 0.000 9.632 0.004 112 77.058 3.436 125 115.588 7.497 127 115.588 7.497 128 154.117 13.184 129 156.117 20.736 100 269.705 40.801 58 36.705 40.801 58 36.705 40.801 114 423.823 107.303 46. 36.705 53.900 116 462.353 107.303 117 462.353 107.303 120 66.706 157.458 130 516.41 224.20 130 616.470 264.220 140 57.64 367.667 127 693.529 367.667 128 170.588 516.618 129 620.434 520.66 129 660.434 520.66</td> <td>100 0.000 0.000 9.632 0.004 4.1 38.529 0.049 112 17.058 3.436 125 115.588 1.497 129 115.588 1.497 196 115.588 1.697 100 100 100 100 100 269.705 40.801 20.736 101 269.705 40.801 20.736 114 423.823 107.303 20.801 115 462.353 107.303 20.801 114 423.823 107.303 20.801 114 423.823 107.458 107.458 126 539.411 223.401 223.401 127 64.1 263.650 264.630 127 693.529 367.661 46.4630 129 665.600 31.718 66.64.64 759.066 129 666.166 759.066 759.066 759.066 136 176.5</td> <td>100 0.000 0.000 9.632 0.094 112 77.058 3.436 125 115.588 7.497 126 154.11 13.184 167 231.17 20.567 167 231.17 20.567 167 269.705 40.801 168 240.801 20.736 169 269.705 53.900 160 36.235 53.900 114 462.353 107.303 115 365.264 86.918 116 423.823 130.881 117 186.516 157.458 110 577.458 157.458 110 616.470 223.441 12 55.000 311.718 110 616.470 264.220 110 616.470 264.220 119 770.588 516.618 119 770.588 516.618 117 1759.666 126.545</td>	100 0.000 0.000 9.632 0.094 112 77.058 3.436 125 115.588 7.497 126 154.117 13.184 167 2647 20.567 167 231.17 20.567 167 249.705 40.801 58 308.235 53.900 61 346.764 69.203 114 423.823 107.303 126 423.823 130.681 137 462.353 130.681 138 53.441 223.441 10 616.470 264.220 550.00 311.718 57 656.20 454.630 57 656.20 454.630 10 616.470 264.230 10 616.41 223.441 10 616.420 454.630 10 616.400 454.630 10 616.641 454.630 10 616.641	100 0.000 0.000 183 9.632 0.004 112 77.058 3.436 125 115.588 17.497 126 115.588 17.497 127 115.588 17.497 128 195.117 13.184 196 195.117 29.736 100 269.705 40.801 58 38.235 53.900 61 386.764 86.918 114 423.823 107.303 115 59.41 123.441 120 516.823 130.681 130 616.470 253.441 140 616.470 253.441 150 616.470 311.718 150 616.470 311.718 150 616.470 311.718 150 616.470 311.718 150 616.470 311.718 160 616.418 51.646 170.588 516.618 516.618 <	100 0.000 0.000 9.632 0.004 112 77.058 3.436 125 115.588 7.497 127 115.588 7.497 128 154.117 13.184 129 156.117 20.736 100 269.705 40.801 58 36.705 40.801 58 36.705 40.801 114 423.823 107.303 46. 36.705 53.900 116 462.353 107.303 117 462.353 107.303 120 66.706 157.458 130 516.41 224.20 130 616.470 264.220 140 57.64 367.667 127 693.529 367.667 128 170.588 516.618 129 620.434 520.66 129 660.434 520.66	100 0.000 0.000 9.632 0.004 4.1 38.529 0.049 112 17.058 3.436 125 115.588 1.497 129 115.588 1.497 196 115.588 1.697 100 100 100 100 100 269.705 40.801 20.736 101 269.705 40.801 20.736 114 423.823 107.303 20.801 115 462.353 107.303 20.801 114 423.823 107.303 20.801 114 423.823 107.458 107.458 126 539.411 223.401 223.401 127 64.1 263.650 264.630 127 693.529 367.661 46.4630 129 665.600 31.718 66.64.64 759.066 129 666.166 759.066 759.066 759.066 136 176.5	100 0.000 0.000 9.632 0.094 112 77.058 3.436 125 115.588 7.497 126 154.11 13.184 167 231.17 20.567 167 231.17 20.567 167 269.705 40.801 168 240.801 20.736 169 269.705 53.900 160 36.235 53.900 114 462.353 107.303 115 365.264 86.918 116 423.823 130.881 117 186.516 157.458 110 577.458 157.458 110 616.470 223.441 12 55.000 311.718 110 616.470 264.220 110 616.470 264.220 119 770.588 516.618 119 770.588 516.618 117 1759.666 126.545

837.023 CM/SEC

THE TERMINAL VELOCITY OF A LIQUID DROP BY BEST'S EQUATION IS

DP = 0.400000 RHO = 0.4000213 SIGMA = 1.000000 XMU = 0.0001789 RE = 0.2821E 04 THE TERMINAL VELOCITY IS 1040.483 CM/SFC

THE DISTANCE DROPPED IN AIR AS A FUNCTION OF VELOCITY BY A SPHERICAL PARTICLE OF GIVEN DIAMETER STARTING FROM REST

VELOCITY RATIO	0-00-0		00000	0,079	0.120	0.159	0.200	0.240	0.280	0.319	0,360	0*400	0.439	0.480	0,519	0*260	0.000	0.639	0.679	0.720	0.759	0.800	0.829	0.879	0.919	0*60	0.979
DISTANCE	000-0	011.0	401°1	4.007	8,739	15,363	23.957	34.621	47.483	62.698	80.460	101,006	124,634	151,711	182,702	218,202	258,986	306.084	360.901	425.429	502-605	597,032	716,519	675.971	1109.848	1535,598	2009.908
VELOCITY CM/SEC	0.00	101.01	41.619	83.238	124,857	165.477	208.096	249.715	291,335	332,954	374.573	416,193	457.812	499.431	541.051	582.670	624,289	665.909	707.528	749.147	790.767	832,386	874.005	915,625	957.244	998.863	1019-673
JIMF. SEC	0.0000	0.03043	2821000	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0.12872	0.17261	0.21724	0.26278	0.30941	9.35734	0.40681	0.45809	0.51150	0.56744	0.62641	0.68899	Je 7559£	C. 52836	C-90755	0.99547	1.0949A	1,21651	1.34960	1.52658	1.77461	2.20657	2.67364

THE TERMINAL VELOCITY OF A LIGUID DROP BY BEST'S EQUATION IS

869-194 CM/SEC

0.4503000	0.001213	1.00000	0.0001789	0.33885 04
	H	×	н	н
96	Q# &	SIGMA	Dix X	æE

THE TERMINAL VELOCITY IS 1110+554 CM/SEC

THE DISTANCE DROPPED IN AIR AS A FUNCTION OF VELOCITY BY A SPHERICAL PARTICLE OF GIVEN DIAMETER STARTING FROM REST

VELOCITY RATIO	000*0	0000	0.039	0.079	0.119	0.159	0.199	0.239	0.279	0.319	0.359	0.399	0.439	0.479	0.519	0.539	0.599	0.639	0.679	0.719	0.759	0.799	0.839	0.879	0.919	0.959	0.979
DISTANCE	000*0	0.125	1.262	4.563	9.949	17-482	27.252	39.368	53.972	71.238	91,382	114,669	141,431	172,080	207.139	247,273	293,352	346.530	408.387	481.156	568.135	674.492	808,995	988,375	1251,326	1729.709	2262.435
VĒLOCITY CM/SEC	000*0	11,105	44.422	86.644	133,266	177-688	222-110	266.533	310.955	355.377	399.799	444.221	488.644	533.066	577.488	621.910	666.332	710.755	755.177	799.599	844.021	888.443	932.865	977.288	1021.710	1066-132	1086.343
TIME SEC	000000	0.01134	0.04543	0.09115	0.13731	0.18408	0.23162	0.2R010	0.32970	0.38066	0.43322	0.48767	0.54435	0.60369	0.66618	0.73246	0. F0336	0.47994	0.96366	1.05656	1,16163	1.28355	1.43024	1.51678	1.87805	2.33279	2.42428

THE TERMINAL VELOCITY OF A LIQUID DROP BY 9EST'S EQUATION IS 891.9

891.944 CM/SEC

			Y RATIO	WT.	0		•		o- 0			•	Ø (2 0	6	6.	•	9 . (₽ •	6	6		9	6	6	9	•	6
		: :	DISTANCE VELOCITY RATIO	 	00000				122 0e119 538 0-150			-1		777 00 70 00 70 70 70 70 70 70 70 70 70		_	i		537 0-630 637 0-639						321 0.679	066 0.919		264 0.979
	1174.606 CM/SEC	AIR AS A FUNCTION OF ICLE OF GIVEN DIAMETER	:				:	•	52 110.122 37 10.538					70 TOTAL BEG					55 37 385 537 485 537			:			53 1096.321			14 2504,264
1.000000 0.0001789 0.3982E 04	THE TERMINAL VELOCITY IS	THE DISTANCE DROPPED IN AIR VELOCITY BY A SPHERICAL PARTICLE STARTING FROM REST	VELOCITY	CM/SEC	000*0	11.746	46.984	100 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	766*0 * 1	234.921	281.905	328.889	475a676	464.847	516.826	563.811	610-795	657-779	751.748	798,732	845.716	892,700	939.685	986,669	1033-653	1080-637	1127.622	1151.11
SIGNA II	THE TERMI	THE D VELOCITY STARTING	ui s H	SEC	000000	0.01199	0.04804	75960-0	0-14516	0.24475	0.29590	0.34822	0.40194	0-51464	0.57429	0.53669	C-70237	0.77201	0.97682	1.01463	1.11200	1.2220B	1.34974	1.50325	1.69837	1.97150	2.44664	2.96001

907.895 CM/SEC THE TERMINAL VELOCITY OF A LIQUID DROP BY BEST'S EQUATION IS // PAUS

APPENDIX B

COMPUTER PROGRAM FOR DISTANCE TRAVELLED
FROM REST TO UPWARD TERMINAL VELOCITY FOR
SPHERES IN A VERTICAL AIR STREAM

// JOB T	
LOG DRIVE CART SPEC CART AVAIL PHY DRIVE FROC 3302 6302 0600	
V2 MIN ACTUAL 16K CONFIG 16K	
mus //	
#ONF INTEGFRS #LIST ALL	
FUNCTION CDREIRE)	
THIS FUNCTION COMPUTES THE PROD	
AND REYNOLDS NUMBER FOR A SPHERE AS A REYNOLDS NUMBER LESS THAN 10000	
C CONSTANT COEFFICIENTS	
A1=1.0/24.	
A7=-2-3363*1.F-04 A3=2-0154*1.F-04	
A4=6.9105*1.E=C9	
PC=1.29536 21.0.86.1 E.01	
A2=4.6677#1.F+C2	
R3±1•1235⊁1•E∞Ω <u>3</u>	
C CHOOSE THE APPROPRIATE FOLYNOMIAL	
IF[BF-4.012,7,7	
C INITIAL ESTIMATE	
! 	
3 CORF = 24.0	
4 X#24#RE	
C REGIN NEWTON METHOD ITERATION	
FX=A]=X+A/#X***/-A3*X**/0+A4*X**/0+A4=RF FDX=AA)=X+V**X+V**A3*X**/-A*X**/-A*X***/-A*X**/-A*	

最近的技術の開発を発生を行うという。 ままから かいかんし かんしょう かんしゅうかん しゅうしゅうしょ アフト・ファ

C CHECK FOR CONVERGENCE C FPS=1.6=06 IF (ARSIDELX/X)=EPS)5,5,6 S CDRF=X/RF G TO 50 C CONTINUE C INITIAL ESTIMATE C TO = 1.0 ELOG = 0.434294481903252 X=ALOGICD=RE**2)*ELOG C RFGIN NEWTON WETHOD ITERATION C DO 24 ITER=1.20 FX=R0+B1*X+B2*X**2+B3*X**3 - ALOGIRE)*ELOG			
FPS=1.6-06 IF (ARS (DFLX/X)=EPS)5.5.6 S CDRF=X/RF GO TO 50 6 CONTINUE GO TO 29 INITIAL ESTIMATE 7 CD = 1.0 ELOG = 0.434294481903252 X=ALOG (CD*RE**2)*ELOG RFGIN NEWTON METHOD ITERATION DO 74 ITER=1.20 FX=0.4B2*X**2+83*X**3 - ALOG (RE)**ELOG			
INITIAL ESTIMATE 7 CD = 1.0 ELOG = 0.434294481903252 x=ALOG(CD*RE**2)*ELOG RFGIN NEWTON WETHOD ITERATION DO 74 ITER=1.20 FX=0.94B1*X+B2*X**2+83*X**3 - ALOG(RE)*ELOG	;		
BFGIN NEWTON METHOD ITERATION DO 24 ITER=1.20 FX=0.0+B1=X+B2=X*=2+83=X*=3 - ALOG(RE) +ELOG			
ドワンエロ1・フィキロフキと・4月ミキメキシ			
DELX=FX/FPX X=X-DELX C C CHECK FOR CONVERGENCE C			
FPS=1.F-06 IF(ABS(DFLX/X)-EPS)22.22.24 22 CDRF=10.***/RE			
C FORMATS FOR OUTPUT STATEMENTS C 202 FORMAT(16HO NO CONVERGENCE) C FND			·
710%S A1(R)=0002 82(R)=000E			BOIR 1=000A FPXIR 1=0016
DFLX(P)=0018 EPS(P)=001A COIR)=001C STATFWENT ALLOCATIONS	ELOG(R)=001E	ITER(I)=0028	

	P SAR SUBIR	.100000E-05=0034 .466770E 01=0040 .200000E 01=004C						***************************************								
	FAXI SKRT SCOMP	-201540E 01≈0032 -100000E 00≈003E -100000E-04=004A														
	FSTO FSBR	•10000CE-03=003C •98600E 01=003C •4C0000E 01=0048										,				
	FMPY FDIV FLD	.233630E 01=002E .129536E 01=003A .100000E-02=0046	3=0057 4=0058	4 2 5	(X			0022				TERWINAL VELOCITY	AS A FUNCTION OF			 яно)
	i	.24000CE 02=002C .100000E=08=0038 .112350F 01=0044 .434294F 00=0050	35 2=0056	CORE ILES 42 PROGRAM	IDDRESS IS COGS (HEX)			9E40 58 CNT			GWA + XMU+RE+VT	표 :	Y			180 FRHO =4.2*(5]GWA - RHO)+G=XNU/(3.0*RHO) VT=(FRHO+RN*#2/(DRN)==[1.0/3.0)
PAGE 3 50 =0100 FEATURES SUPPORTED ONE WORD INTEGERS	CALLED SUPPROGRAMS FAPS FALOG FAXE REAL CONSTANTS	.100000F 01=002A .691050F 01=0036 .100000F-01=0042 .300000F 01=004E	1=0054 Zn=0355	CORF REQUIREMENTS FOR CORE COMMON 0 VARIABLES	RELATIVE FNTRY POINT ACCRESS	END OF COMPILATION	d.lu //	#STOPE XS UA CO	// FOR	#ONE WORD INTEGERS #LIST ALL	COMMON DP+RHO+SIGMA+XMU+RE+VT	THIS SUBROUTING CALCULATES	C PARTICLE DESCITY AND DIAPTER		XVU = KMUZRHO	 TRHO =4.0#(516WA - RHO)#G#XNU/(VT=(FRHO#RN##2/CORN)##(1.0/9.0)

,

.

00 6 ITFR=1,100 RF =VT+DP/XNU 0L?V = VT VT=(FRHO*PF+*2/CORE(RE))***(1.00 C CHFCK CONVERGENCE					
	##[1.0/3.0]				
FPS = 1.E-03			!	: : : : : : : : : : : : : : : : : : : :	
IF(ASS(VT-CLOV)- EPS)5,566 5 CONTINUE	9.6				
6 CONTINUE					
WRITE(3.20n)					
3C K* TUKK					
C EORMAT FOR CUITDUT STATEMENT	H.				
200 FCRWAT(16HC NO CONVERGENCE)	CE)				
CKO					
TIONS	1	1			
	SIGMA(RC	TFFA	XWU(RC)=7FF8	RE (RC) = TFF6	VT(RC)=7FF4
G(R)=0000 XNU(R)=0002)=000 4	RN(R)=5006	FR40(R)=0008	OLDV(R)=DOOA
EPS(R)=000C ITER(I)=0014					
	;				
و ا	=00AE 30 =008B				1.
FEATURES SUPPORTED					
ONE WORD INTEGERS			,		
CALLFD SURPROGRAMS CDRF FABS FAXR FSUR	FMPY FDIV FLD	D FSTO	FDVR FAXI	SWRT SCOMP	
REAL CONSTANTS					
.981000F 03=0016 .240000E 02=0018	02=0018 .100000E 01=001A		.400000E 01=001C	-300000E 01=001E	.100000E-02=0020
INTEGER CONSTANTS 7=0072	=9024 3=0025	1			
DUIREMENTS FOR SAM36					
COMMON 12 VARIABLES 2	22 PROGRAM 168				
RELATIVE FMTRY POINT ANDRESS IS 0030	5 0030 (HEX)				

THE OF COMPILATION

CALCULATE TIVE AND DISTANCE FOR EACH VELOCITY INCREMENT PP IS PARTICLE DIAMETER CM.
PMG IS AIR DENSITY GM PER CURIC CM.
SIGWA IS PARTICLE DENSITY GW PER CURIC CM.
XMJ IS AIR DYNAMIC VISCISITY GM PER CW SEC. 000F READ(2.1001DP.RHO.SIGMA.XWJ.U CALL SAW36 WPITE(3.2001DP.RHO.SIGMA.XMU.RE.U WPITE(3.2011VT WRITE(3.202) WRITE(3.203) DB CNT COMMON DP.RHO.SIGMA.XMU.RE.VT PFF = DP#RHO/XMU
A = 981.0 +RHO/SIGMA)
A = 0.75#XMU/(SIGWA*DP#*2)
V\$TAR = U - VT

DFLV ≈ V\$TAR/100.0 UA 58436 08 ADDR 3E62 40ITE(3-204) T+V+X+V9 CALCULATE CONSTANTS 00 26 I = 1.1FPQ V = FLOAT(I)* DELV VS = U - V PF = VS*RFF // FOR WORD INTEGERS #10CS(CARD) #10CS(1132 PRINTER) #LIST ALL INPUT DATA Ş +STOPE H CAGT ID 0302 0376 11 000 UU U

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			VI(RC)=7FF4 DELVIR)=500A DELIIR)=6016 XIARIR)=6022 NSIOPII)=6020	#0161 4 #0123 #0264 27 #0284	TELOAT CARDZ	•950000E 02≈0038	
			RE(RC) = 7FF6 VSTAR(R) = 0008 VS(R) = 0014 VTAR(R) = 0020 IS(R) = 0020	=011E 205 =0123 1 =0298 24 =02A4 26	FSBR FDVR FAXI	0 +00000E 00=0036	
\$510.4/	S A FUNCTION OF SIVEN DIAMETER ISTANCE,8X4	4 .15X. BY BEST'S EQUAT	XVJ(RC)=7FF8 B(R)=0006 VR(R)=0012 TTAR(R)=001E I(I)=0028	9E 203 =00E6 204 8C 22 =0292 23	FDIV FLO FSTO	2 *100000E 03=0034 E *114700E 01=0040	94
+0 = \$FI0.6/ \$FI0.7/IOH RE = VELOCITY IN CITEL AL	FORWAT(ING. 50H THE DISTANCE TRAVELLED IN AIR AS A FUNCTION OF 51H VFLOCITY RY A SPHERICAL PARTICLE OF SIVEN DIAMETER 27 COPWAT(ING. 5H IME,17X, 9H VELOCITY,13X,9H DISTANCE,8X,15H VFLOCITY RATIO	27 1X.444 SEC #19X#7H CM/SEC #16X#3H CM #15X# 39H V/(U=VT) 274 FORMAT(FR.5, 13X*F10#3) 1X*F10#3} 3X*F6#3} FR.5, 13X*F10#3* 1X*F10#3} 3X*F6#3} FROM TE 62HOTHE TERVINAL VELOCITY OF A LIQUID DROP BY BEST*S EQUATION IS #F10#3*RH CM/SFC } FROM FROM FROM FROM FROM FROM FROM FROM	SIGNA(RC)=7FFA A(R)=9004 T(R)=0010 DXTAR(R)=001C	ł.	FSUB FMPY SIOF SIOI	*75000E 0C=0032	1=0045 4=0046
= \$F10.7/10H RHC \$F10.6/10H XWU = \$F \$F10.2)	31 MGT	IX-44 SEC - 19X = 7H CM/SEC - 16X FR.5. 13X-FID-301IX-FID-3013X-F6-31 10THE TERMINAL VELOCITY OF A LIGUID 3-3-8H CM/SFC 1	S RHO(RC) = 7FFC REF(R) = 0002 V(Q) = 000E DFLX(R) = 001A VTR(R) = 0026	48 200 ≈004D 62 10 =0269	XP FAXR FADD RT SCOMP SFIO	.1CC000E 01=0030 .94300E 03=003C	3=0043 68=0044
200 FORWAT(10H1DP 11PH SIGWA = 1 21PH COMMANDE	1 AH CYSEC) 202 FORWAT(1H0. 50H 1/ 51H VFL 203 FORWAT(1H0. 50H 51H VFL 203 FORWAT(1H0. 5H 135H VFL	2/ 39H V/(U=VT)) 2r4 FCRMAT(FR.5, 13X,FID. 2r5 FORMAT(62HOTHE TERVINAL 11ON IS *FID.3,RH CM/SFC) FND	VARIBRE ALLOCATIONS PP(RC)=77FF U(R.)=0000 X(R.)=020C CDBX(R.)=0018 VRTAR(F.)=0018	7 ALLOCATI 747 111 232 6 294 30	CALLE SUPPOGRAMS CALLE SUMPROGRAMS SPW36 CORE FEXP	REAL CONSTANTS *9ALDCN= 03=002E *3NOCONF-CI≖GN3A	integer constants 2=0042 3=0
	1			!			

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46 PROGRAW

COME REDUISEMENTS FOR

i FN9 OF COMPILATION // XFQ

0.0470030	0.001213	2*600000	0.0001789	n.1141E 03	700,00
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THE DOWNWARD TERMINAL VELOCITY IN STILL AIR IS 358.114 CM/SEC

THE DISTANCE TRAVELLED IN AIR AS A FUNCTION OF VELOCITY BY A SPHERICAL PARTICLE OF GIVEN DIAMETER STAPTING FROM REST

																										ABBER			
VELOCITY RATIO	V/ (U-V1)	000 0	0.010	0*0*0	080*0	0.120	0.160	0.199	0.240	0.280	0,320	0•360	0.399	0.439	0.480	0.519	0,560	009*0	0.640	0.679	0.720	0.759	661.99	0.840	0.876	0.879	0.919	096*0	0.979
DISTANCE	₹	000*0	900*0	2.067	0.251	0.563	1,018	1.632	2.424	3.415	4-633	6.107	7.875	9.981	12,481	15.442	18,951	23,122	28,101	34,090	41,376	50.377	61,751	76.612	95.000	97.087	128.091	186.380	252.794
VELOCITY	CM/SEC	000*0	3.418	13,675	27,350	41.026	54.701	68.377	82,052	95.727	169.403	123.078	136.754	150.429	164.134	177.780	191.455	205-131	218.806	232.4RI	246,157	259.832	273.508	287.183	299.635	300.859	314,534	328,209	335.047
un II	SFC	0-0000	0.00192	0.00784	_	0.02477	0.03394	0.04363	0.05392	0.06486	0.07653	0.0R902	0.10244	0.11693	0.13264	0.14978	0.15861	0.18545	0.21273	0.23906	0.26927	0.30458	6.34693	0.19957	0.44179	0.44873	C.54879	0.74875	0.9477R

185.096 CM/SEC THE TERMINAL VELOCITY OF A LIGUID DROP BY REST'S EQUATION IS

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1. ORIGINATING ACTIVITY	2. DOCUMENT SECURITY CLASSIFICATION UNCLASSIFIED
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2 DOCUMENT TITLE	
THE DISTANCE TRAVELLED FROM REST	TO TERMINAL VELOCITY BY A SPHERE IN AIR (U)
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)	Technical Note
& AUTHOR(S) (Lest name, first name, middle initial)	
Mellsen, Stanley B.	
6. DOCUMENT DATE October 1978	7a. TOTAL NO. OF PAGES 7b. NO. OF REFS
E. PROJECT OR GRANT NO.	96. ORIGINATOR'S DOCUMENT NUMBER(S)
20-90-03 WUD 13E01	SUFFIELD TECHNICAL NOTE NO. 425
Sb. CONTRACT NO.	9b. OTHER DOCUMENT NO.(8) (Any other numbers that may be assigned this document)
10. DISTRIBUTION STATEMENT	
"UNLIMITED DISTRIBUTION"	
11. SUPPLEMENTARY NOTES	12. SPONSORING ACTIVITY
13. ABSTRACT	
spherical drops starting from res	as a function of velocity for falling at was calculated. This was done for ermine the travel distance required for

spherical drops starting from rest was calculated. This was done for 1 to 5 millimetre spheres to determine the travel distance required for designing experiments where velocities approaching terminal are required. The results showed that 80 percent of terminal velocity is reached after spheres of unit density and diameter of 5 millimetres have fallen from rest through a distance of 7.5 metres. To achieve 85 percent of terminal velocity, an increase of only 5 percent, 9.5 metres is required. Also calculated was the velocity of particles blown upward from rest in a vertical airstream. This was done to provide information for comparison of experimental to theoretical results on the effect of dust on aerodynamic drag.

(U)

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KEY WORDS

Aerosols - Travel

Drops (Liquid)

Dust Particles

Aerodynamic Drag

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